IN THE SPECIFICATION

Please amend page 1 by inserting the following heading between the title of the invention and the first paragraph:

"FIELD OF THE INVENTION"

Please amend page 1 by inserting the following heading between the first and second paragraphs:

"BACKGROUND OF THE INVENTION"

Please amend page 3 by inserting the following heading on line 6:

"SUMMARY OF THE INVENTION"

Please amend page 9 by inserting the following heading on line 12:

"BRIEF DESCRIPTION OF THE DRAWINGS"

Please amend page 10 by inserting the following heading on line 3:

"DETAILED DESCRIPTION OF THE INVENTION"

Please amend page 19 by inserting the following language between the "CLAIMS" heading and claim 1:

"I/We claim:"

Please amend page 3 line 7 as follows:

"~~In summary, i~~In accordance with the present invention at least one of the booster"

Please amend pages 3-9 by deleting the text beginning on page 3 line 22 and ending on page 9 line 11 as follows:

"~~Due to the reduced levels of size, noise and vibration associated with a centrifugal compressor system in comparison to the conventional dry pumps, replacing one or both of the conventional backing and booster pumps with a pump comprising a multi-stage centrifugal compressor mechanism can enable at least part of the pumping~~

~~arrangement to be mounted on the processing tool, thereby potentially avoiding the expensive long runs of large diameter pipe work.~~

~~It is desirable to perform the evacuation of a vacuum chamber, such as a load lock chamber, from atmospheric pressure to a low pressure as quickly as possible. The faster that this evacuation can be accomplished, the higher the rate of processing substrates becomes. However, during the initial stages of the evacuation of a chamber from atmospheric pressure using a pump having a multi-stage pumping mechanism, the compression of fluid by the pumping mechanism can cause the fluid pressure to increase above atmospheric pressure. This can result in undesirable overloading of the exhaust stages of the pumping mechanism. If such a pump is operated for a significant period in this condition, damage can occur in the form of seals and/or bearings failing, or by impact between the fragile rotating impellers and pump's housing.~~

~~In view of this, in another aspect the present invention provides a multi-stage centrifugal compressor mechanism comprising a housing, a drive shaft rotatably mounted within the housing, a plurality of fixed members disposed within the housing and defining a plurality of interconnected fluid chambers, a plurality of impellers mounted on the drive shaft and disposed relative to the fixed members such that each impeller delivers compressed fluid to a respective fluid chamber, a bypass channel extending between two of the fluid chambers to enable fluid to pass between those chambers without compression, and means for controlling the flow of fluid through the bypass channel. Compressed fluid can thus be conveyed between fluid chambers without compression, which can enable a larger upstream pumping stage to operate at full speed without causing the pumped fluid to be pressurised above atmospheric pressure.~~

~~The control means is thus preferably arranged to open the bypass channel under the influence of a pressure difference between said two of the fluid chambers, and in particular when the pressure in an upstream one of said two of the fluid chambers is greater than the pressure in a downstream one of said two of the fluid chambers.~~

~~In a preferred embodiment, said two of the fluid chambers are adjacent fluid chambers of the compressor mechanism, although one or more other fluid chambers may,~~

~~alternatively, separate these two fluid chambers. For example, one of the fluid chambers may be the first, lowest pressure fluid chamber of the pumping mechanism, and the other fluid chamber by the last, highest pressure fluid chamber of the pumping mechanism. Where these two fluid chambers are adjacent, however, the bypass channel may conveniently pass through the fixed member located between the fluid chambers.~~

~~The control means preferably comprises valve means, for example, a valve member displaceable in use between a closed position and an open position by pressurised fluid. Such a valve member may be conveniently provided by a flap valve, which can be conveniently positioned within a fluid chamber to control the flow of fluid into that fluid chamber from the bypass channel.~~

~~Preferably, the mechanism comprises, for each fluid chamber, a respective bypass channel extending between that fluid chamber and the adjacent downstream fluid chamber, and means for controlling the flow of fluid through each bypass channel.~~

~~Centrifugal compressor mechanisms are susceptible to surging of pumped fluid when the specific flow rate of the pumped fluid through a stage of the compressor mechanism is relatively low. The surging manifests itself in a backflow of fluid into the compressor impeller, and adversely affects the efficient operation of the vacuum pump, and in extreme conditions, may actually damage the pump. In view of this, the mechanism preferably comprises surge control means for controlling surge within the compressor mechanism. Therefore, in a further aspect the present invention provides a multi-stage centrifugal compressor mechanism comprising a housing, a drive shaft rotatably mounted within the housing, a plurality of fixed members disposed within the housing and defining a plurality of interconnected fluid chambers, a plurality of impellers mounted on the drive shaft and disposed relative to the fixed members such that each impeller delivers compressed fluid to a respective fluid chamber, and surge control means for controlling surge within the multi-stage centrifugal compressor mechanism.~~

~~The surge control means preferably comprises means for conveying a stream of fluid to each fluid chamber, and means for controlling the rate of flow of the fluid stream into~~

~~each fluid chamber. In one embodiment, the conveying means is arranged to convey a stream of gas, such as air, nitrogen or an inert gas, to each fluid chamber. In another embodiment, the conveying means is arranged to convey a stream of compressed fluid to each fluid chamber. In either case, the rate of flow through the compressor mechanism can be maintained at a value above that at which surging will occur.~~

~~Where the conveying means is arranged to convey a stream of compressed fluid to each fluid chamber from a downstream fluid chamber, the conveying means preferably comprises, for each fluid chamber, a fluid passage (separate from the previously-mentioned bypass channel) extending between that fluid chamber and the adjacent downstream fluid chamber. These fluid passages are preferably co-axial.~~

~~The means for controlling the rate of flow of the fluid stream into each fluid chamber preferably comprises valve means. The valve means may comprise a series of valves for controlling fluid flow through respective fluid passages or a spool valve for controlling fluid flow through each fluid passage. The valve means is preferably located at least partially within the chamber, thereby avoiding the need to provide external pipe connections. The valve means may be controlled by a separate controller. In order to control the valve means, a pressure sensor may be provided to monitor the pressure of fluid passing through a pump inlet, a signal from the inlet sensor being supplied to a control system which controls the opening and closing of the valve means. In addition, or alternatively, pressure sensors may be provided within the pumping mechanism to monitor pressure fluctuation within the pumping mechanism, and thus detect the onset of surging.~~

~~Each impeller preferably has on one side thereof a plurality of vanes or blades extending between the inner periphery and the outer periphery thereof. Each blade preferably follows a curved path. To facilitate manufacture, each fixed member preferably comprises a disc integral with a respective part of the housing.~~

~~Fluid that is compressed by the compressor mechanism typically becomes hot. In order to cool fluid pumped by the compressor mechanism, particularly at the exhaust stages, the mechanism preferably comprises means for cooling each fixed member.~~

~~For example, a plurality of cooling fins may be provided on one side thereof. Alternatively, or in addition, the cooling means may comprise means for supplying a flow of coolant to each fixed member. This can provide direct cooling of both the cooling fins (where provided) and the fixed plate. The cooling fins may be located between the fixed plate and a diffuser plate for directing a stream of compressed fluid from an impeller to a fluid chamber so that the fins can also provide for cooling of the diffuser plate.~~

~~The present invention also provides a vacuum pump comprising a compressor mechanism as aforementioned.~~

~~Excessive heating of the compressor mechanism may occur if the pump is operated over a relatively long period at a relatively high pressure, for example, if a door to a load lock chamber evacuated by the pump has been inadvertently left open. In order to prevent excessive heating of the pump, the temperature of the pump may be monitored, and the speed of rotation of the compressor mechanism varied in response to the monitored temperature. This can enable the speed of the pump to be reduced in the event of overheating, thereby reducing the temperature within the pump, and preventing the pump from being unduly operated at a high speed for a relatively long period.~~

~~Therefore, the pump preferably comprises means for monitoring the temperature of the pump, and means for controlling the speed of rotation of the shaft in dependence on the monitored temperature. The monitoring means may be conveniently provided by any suitable temperature sensor, such as a thermocouple, located within or in close proximity to the housing. A controller for controlling a motor driving the drive shaft may provide the control means.~~

~~In order to cool the housing, to which heat will be transferred by the pumped fluid, an external cooling system may also be provided, for example, in the form of a cooling jacket extending about at least part of the compressor mechanism.~~

~~Where the pump is to be used as a backing pump, the backing pump may consist of such a multi-stage centrifugal compressor mechanism, in combination with any suitable~~

~~booster pump. Such a booster pump may be provided by a pump comprising such a multi-stage centrifugal compressor mechanism downstream from a molecular drag mechanism, the number of stages of the compressor mechanism (for example, two) being smaller in the booster pump than in the backing pump (for example, six or seven). Alternatively, the conventional combination of booster and backing pumps may be replaced by a single pump, this pump comprising a multi-stage (for example, six or seven stage) centrifugal compressor mechanism downstream from a multi-stage (for example, four stage) molecular drag mechanism. The molecular drag mechanism preferably comprises a multi-stage Holweck mechanism having a plurality of channels arranged as a plurality of helixes. The drag stages may be arranged in series, in parallel for maximum pumped volume, or in a combination of both. In order to minimise the length of the pump the molecular drag mechanism preferably at least partially surrounds a motor for rotating the drive shaft. For instance, where the molecular drag pumping mechanism is a Holweck mechanism, a rotor element of the molecular drag pumping mechanism typically comprises a cylinder mounted for rotary movement with the rotor elements of the compressor mechanism, which cylinder may at least partially surround the motor. This, in a further aspect the present invention provides a vacuum pump comprising a multi-stage centrifugal compressor mechanism comprising a plurality of rotor elements mounted on a rotatably mounted drive shaft, and, upstream therefrom, a molecular drag mechanism comprising at least one rotor element mounted on the drive shaft, wherein the at least one rotor element of the molecular drag mechanism at least partially surrounds a motor for rotating the drive shaft.~~

~~As discussed above, for rapid pump down of a chamber the pump may be provided with valve means for enabling compressed fluid to by-pass one or more of the impellers of the multi-stage centrifugal compressor mechanism, allowing the pump to pump down at full inlet speed even when the exhaust stages of the compressor mechanism are somewhat smaller than the inlet stages. With such a design, the backing pump may become a restriction to the flow of fluid through the pumping arrangement. Therefore, in a preferred arrangement a fluid by-pass conduit is connected between an exhaust from the booster pump and an exhaust from the backing pump, with means being provided for controlling the flow of fluid through the by-pass. Such an arrangement may be provided for any combination of booster and backing pumps.~~"

Please amend page 10 by inserting the following text before line 4 as follows:
"In accordance with the present invention at least one of the booster pump and the backing pump in the conventional pumping arrangement is replaced by a vacuum pump comprising a multi-stage centrifugal compressor system. In one embodiment, both the booster pump and the backing pump are replaced by a single vacuum pump exhausting to atmosphere. In a second embodiment, the booster pump is provided by a similar vacuum pump to the first embodiment, having a reduced number of compressor stages, backed by a backing pump. This backing pump may be a conventional backing pump, or, in accordance with a third embodiment, may be a vacuum pump comprising a multi-stage centrifugal compressor system exhausting to atmosphere. Such a backing pump may be provided with a conventional Roots booster pump. Thus, in one aspect, the present invention provides a vacuum pump comprising a multi-stage centrifugal compressor mechanism for receiving fluid to be pumped and exhausting pumped fluid substantially at atmospheric pressure.

Due to the reduced levels of size, noise and vibration associated with a centrifugal compressor system in comparison to the conventional dry pumps, replacing one or both of the conventional backing and booster pumps with a pump comprising a multi-stage centrifugal compressor mechanism can enable at least part of the pumping arrangement to be mounted on the processing tool, thereby potentially avoiding the expensive long runs of large diameter pipe work.

It is desirable to perform the evacuation of a vacuum chamber, such as a load lock chamber, from atmospheric pressure to a low pressure as quickly as possible. The faster that this evacuation can be accomplished, the higher the rate of processing substrates becomes. However, during the initial stages of the evacuation of a chamber from atmospheric pressure using a pump having a multi-stage pumping mechanism, the compression of fluid by the pumping mechanism can cause the fluid pressure to increase above atmospheric pressure. This can result in undesirable overloading of the exhaust stages of the pumping mechanism. If such a pump is operated for a significant period in this condition, damage can occur in the form of seals and/or bearings failing, or by impact between the fragile rotating impellers and pump's housing.

In view of this, in another aspect the present invention provides a multi-stage centrifugal compressor mechanism comprising a housing, a drive shaft rotatably mounted within the housing, a plurality of fixed members disposed within the housing and defining a plurality of interconnected fluid chambers, a plurality of impellers mounted on the drive shaft and disposed relative to the fixed members such that each impeller delivers compressed fluid to a respective fluid chamber, a bypass channel extending between two of the fluid chambers to enable fluid to pass between those chambers without compression, and means for controlling the flow of fluid through the bypass channel. Compressed fluid can thus be conveyed between fluid chambers without compression, which can enable a larger upstream pumping stage to operate at full speed without causing the pumped fluid to be pressurised above atmospheric pressure.

The control means is thus preferably arranged to open the bypass channel under the influence of a pressure difference between said two of the fluid chambers, and in particular when the pressure in an upstream one of said two of the fluid chambers is greater than the pressure in a downstream one of said two of the fluid chambers.

In a preferred embodiment, said two of the fluid chambers are adjacent fluid chambers of the compressor mechanism, although one or more other fluid chambers may, alternatively, separate these two fluid chambers. For example, one of the fluid chambers may be the first, lowest pressure fluid chamber of the pumping mechanism, and the other fluid chamber by the last, highest pressure fluid chamber of the pumping mechanism. Where these two fluid chambers are adjacent, however, the bypass channel may conveniently pass through the fixed member located between the fluid chambers.

The control means preferably comprises valve means, for example, a valve member displaceable in use between a closed position and an open position by pressurised fluid. Such a valve member may be conveniently provided by a flap valve, which can be conveniently positioned within a fluid chamber to control the flow of fluid into that fluid chamber from the bypass channel.

Preferably, the mechanism comprises, for each fluid chamber, a respective bypass channel extending between that fluid chamber and the adjacent downstream fluid chamber, and means for controlling the flow of fluid through each bypass channel.

Centrifugal compressor mechanisms are susceptible to surging of pumped fluid when the specific flow rate of the pumped fluid through a stage of the compressor mechanism is relatively low. The surging manifests itself in a backflow of fluid into the compressor impeller, and adversely affects the efficient operation of the vacuum pump, and in extreme conditions, may actually damage the pump. In view of this, the mechanism preferably comprises surge control means for controlling surge within the compressor mechanism. Therefore, in a further aspect the present invention provides a multi-stage centrifugal compressor mechanism comprising a housing, a drive shaft rotatably mounted within the housing, a plurality of fixed members disposed within the housing and defining a plurality of interconnected fluid chambers, a plurality of impellers mounted on the drive shaft and disposed relative to the fixed members such that each impeller delivers compressed fluid to a respective fluid chamber, and surge control means for controlling surge within the multi-stage centrifugal compressor mechanism.

The surge control means preferably comprises means for conveying a stream of fluid to each fluid chamber, and means for controlling the rate of flow of the fluid stream into each fluid chamber. In one embodiment, the conveying means is arranged to convey a stream of gas, such as air, nitrogen or an inert gas, to each fluid chamber. In another embodiment, the conveying means is arranged to convey a stream of compressed fluid to each fluid chamber. In either case, the rate of flow through the compressor mechanism can be maintained at a value above that at which surging will occur.

Where the conveying means is arranged to convey a stream of compressed fluid to each fluid chamber from a downstream fluid chamber, the conveying means preferably comprises, for each fluid chamber, a fluid passage (separate from the previously-mentioned bypass channel) extending between that fluid chamber and the adjacent downstream fluid chamber. These fluid passages are preferably co-axial.

The means for controlling the rate of flow of the fluid stream into each fluid chamber preferably comprises valve means. The valve means may comprise a series of valves for controlling fluid flow through respective fluid passages or a spool valve for controlling fluid flow through each fluid passage. The valve means is preferably located at least partially within the chamber, thereby avoiding the need to provide external pipe connections. The valve means may be controlled by a separate controller. In order to control the valve means, a pressure sensor may be provided to monitor the pressure of fluid passing through a pump inlet, a signal from the inlet sensor being supplied to a control system which controls the opening and closing of the valve means. In addition, or alternatively, pressure sensors may be provided within the pumping mechanism to monitor pressure fluctuation within the pumping mechanism, and thus detect the onset of surging.

Each impeller preferably has on one side thereof a plurality of vanes or blades extending between the inner periphery and the outer periphery thereof. Each blade preferably follows a curved path. To facilitate manufacture, each fixed member preferably comprises a disc integral with a respective part of the housing.

Fluid that is compressed by the compressor mechanism typically becomes hot. In order to cool fluid pumped by the compressor mechanism, particularly at the exhaust stages, the mechanism preferably comprises means for cooling each fixed member. For example, a plurality of cooling fins may be provided on one side thereof. Alternatively, or in addition, the cooling means may comprise means for supplying a flow of coolant to each fixed member. This can provide direct cooling of both the cooling fins (where provided) and the fixed plate. The cooling fins may be located between the fixed plate and a diffuser plate for directing a stream of compressed fluid from an impeller to a fluid chamber so that the fins can also provide for cooling of the diffuser plate.

The present invention also provides a vacuum pump comprising a compressor mechanism as aforementioned.

Excessive heating of the compressor mechanism may occur if the pump is operated over a relatively long period at a relatively high pressure, for example, if a door to a load lock chamber evacuated by the pump has been inadvertently left open. In order to prevent excessive heating of the pump, the temperature of the pump may be monitored, and the speed of rotation of the compressor mechanism varied in response to the monitored temperature. This can enable the speed of the pump to be reduced in the event of overheating, thereby reducing the temperature within the pump, and preventing the pump from being unduly operated at a high speed for a relatively long period.

Therefore, the pump preferably comprises means for monitoring the temperature of the pump, and means for controlling the speed of rotation of the shaft in dependence on the monitored temperature. The monitoring means may be conveniently provided by any suitable temperature sensor, such as a thermocouple, located within or in close proximity to the housing. A controller for controlling a motor driving the drive shaft may provide the control means.

In order to cool the housing, to which heat will be transferred by the pumped fluid, an external cooling system may also be provided, for example, in the form of a cooling jacket extending about at least part of the compressor mechanism.

Where the pump is to be used as a backing pump, the backing pump may consist of such a multi-stage centrifugal compressor mechanism, in combination with any suitable booster pump. Such a booster pump may be provided by a pump comprising such a multi-stage centrifugal compressor mechanism downstream from a molecular drag mechanism, the number of stages of the compressor mechanism (for example, two) being smaller in the booster pump than in the backing pump (for example, six or seven). Alternatively, the conventional combination of booster and backing pumps may be replaced by a single pump, this pump comprising a multi-stage (for example, six or seven stage) centrifugal compressor mechanism downstream from a multi-stage (for example, four stage) molecular drag mechanism. The molecular drag mechanism preferably comprises a multi-stage Holweck mechanism having a plurality of channels arranged as a plurality of helixes. The drag stages may be arranged in series, in parallel for maximum pumped volume, or in a combination of both. In order to minimise

the length of the pump the molecular drag mechanism preferably at least partially surrounds a motor for rotating the drive shaft. For instance, where the molecular drag pumping mechanism is a Holweck mechanism, a rotor element of the molecular drag pumping mechanism typically comprises a cylinder mounted for rotary movement with the rotor elements of the compressor mechanism, which cylinder may at least partially surround the motor. This, in a further aspect the present invention provides a vacuum pump comprising a multi-stage centrifugal compressor mechanism comprising a plurality of rotor elements mounted on a rotatably mounted drive shaft, and, upstream therefrom, a molecular drag mechanism comprising at least one rotor element mounted on the drive shaft, wherein the at least one rotor element of the molecular drag mechanism at least partially surrounds a motor for rotating the drive shaft.

As discussed above, for rapid pump down of a chamber the pump may be provided with valve means for enabling compressed fluid to by-pass one or more of the impellers of the multi-stage centrifugal compressor mechanism, allowing the pump to pump down at full inlet speed even when the exhaust stages of the compressor mechanism are somewhat smaller than the inlet stages. With such a design, the backing pump may become a restriction to the flow of fluid through the pumping arrangement. Therefore, in a preferred arrangement a fluid by-pass conduit is connected between an exhaust from the booster pump and an exhaust from the backing pump, with means being provided for controlling the flow of fluid through the by-pass. Such an arrangement may be provided for any combination of booster and backing pumps."

Please amend page 18 by inserting the following text beginning line 16 as follows:

"While the foregoing description and drawings represent the preferred embodiments of the present invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the true spirit and scope of the present invention."